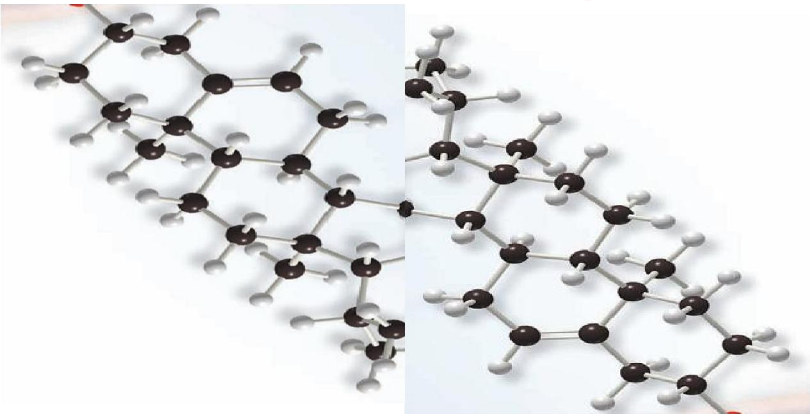
General Organic and Biological Chemistry



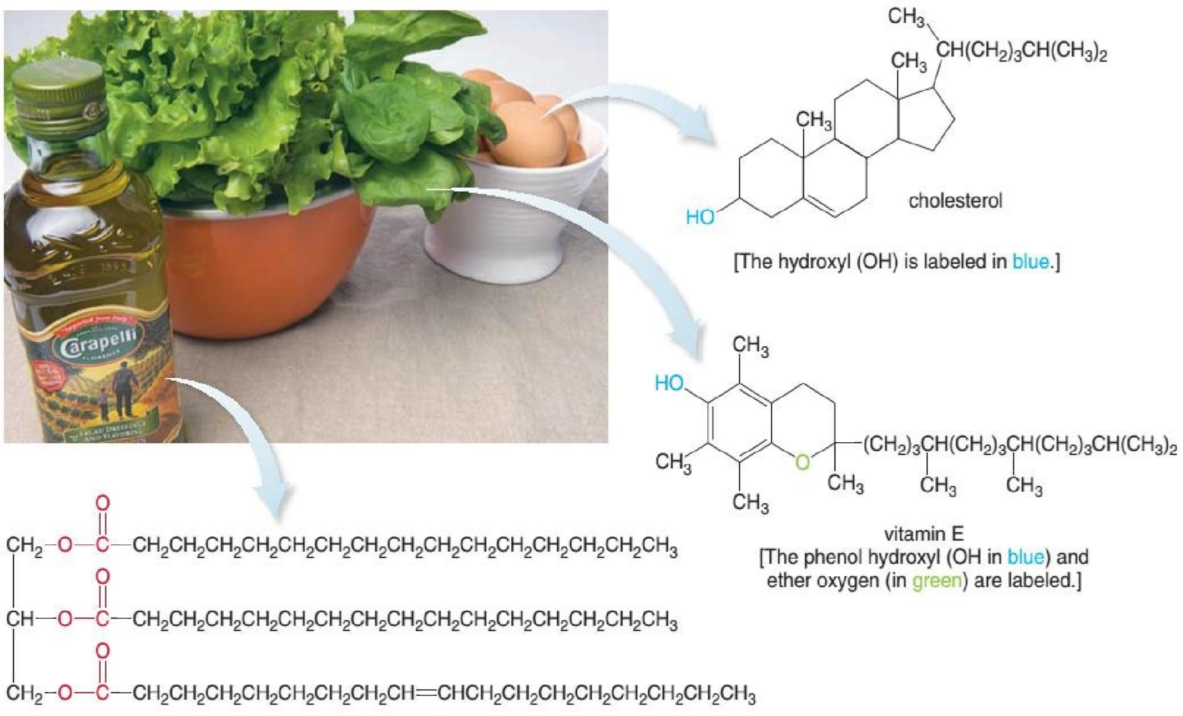
Ass Prof Dr.Mokhtar Al-Ghorafi

Lipids

lipids, biomolecules that contain many carbon–carbon and carbon–hydrogen bonds, making them soluble in organic solvents and insoluble in water.

Lipids are biomolecules that are **soluble in organic** solvents and insoluble in water.

Common lipids include triacylglycerols in vegetable oils, cholesterol in egg yolk, and vitamin E in leafy greens



cholesterol

[The hydroxyl (OH) is labeled in blue.]

vitamin E

[The phenol hydroxyl (OH in blue) and ether oxygen (in green) are labeled.]

triacylglycerol

[The three ester groups are labeled in red.]

- **Lipids contain a large number of nonpolar carbon–carbon and carbon–hydrogen bonds.**

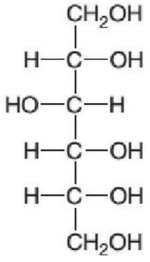
- **In addition, most lipids have a few polar bonds that may be found in a variety of functional groups. For example, a triacylglycerol contains three esters, cholesterol possesses a hydroxyl group, and vitamin E has both a phenol (an OH group on a benzene ring) and an ether.**

- **The size of these functional groups is small compared to the overall size of the molecules.**

- **As a result, lipids are nonpolar or weakly polar molecules that are very soluble in organic solvents like hexane (C6H14) and insoluble in a polar medium like water.**

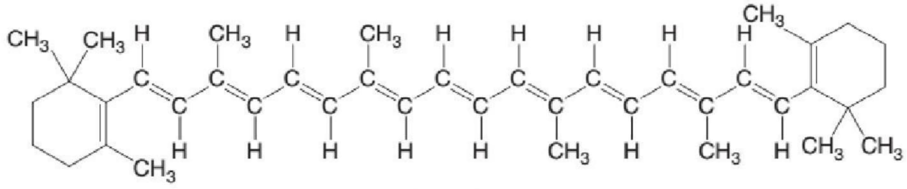
Which compounds are likely to be lipids?

a.



sorbitol

b.



β-carotene

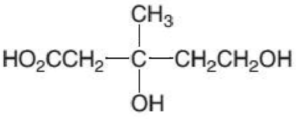
ANALYSIS Lipids contain many nonpolar C—C and C—H bonds and few polar bonds.

SOLUTION a. Sorbitol is not likely to be a lipid since it contains six polar OH groups bonded to only six carbon atoms.

b. β-Carotene is likely to be a lipid since it contains only nonpolar C—C and C—H bonds.

Which compounds are likely to be lipids?

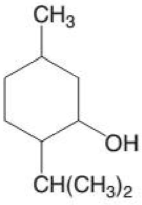
a.



$HO_2CCH_2-\overset{CH_3}{\underset{OH}{C}}-CH_2CH_2OH$

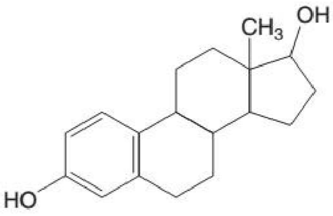
mevalonic acid

b.



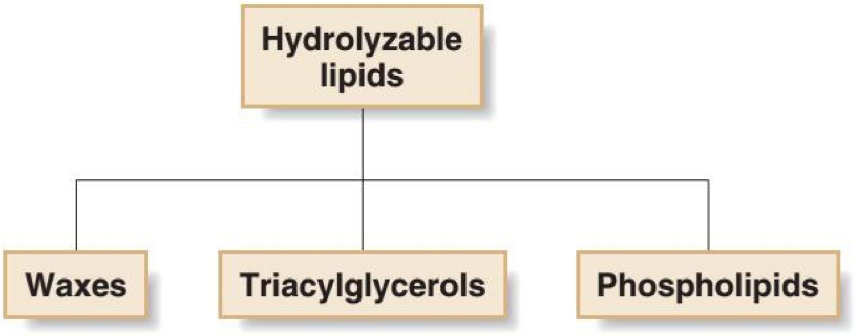
menthol

c.



estradiol

Hydrolyzable lipidscan be converted into smaller molecules by hydrolysis with water.
We will examine three subgroups: waxes, triacylglycerols, and phospholipids.

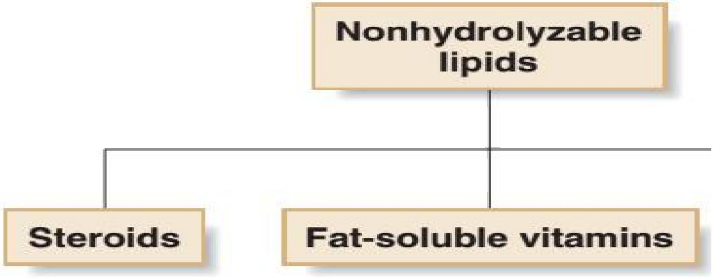

Hydrolyzable lipids

Waxes

Triacylglycerols

Phospholipids

Nonhydrolyzable lipids can not be cleaved into smaller units by aqueous hydrolysis.


Nonhydrolyzable lipids

Steroids

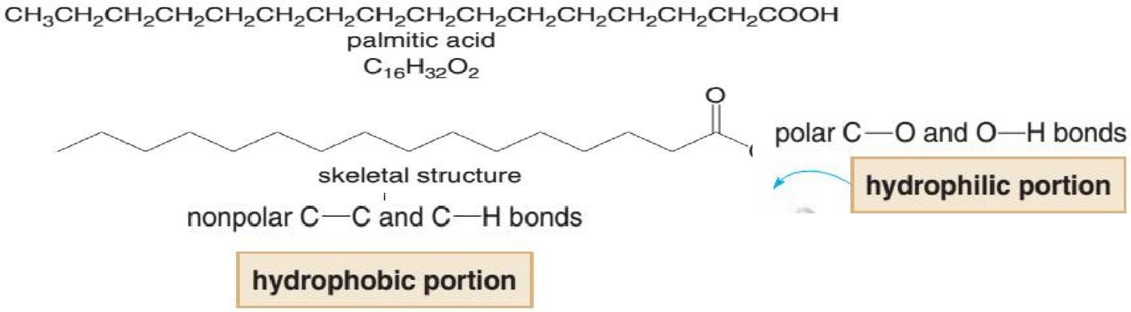
Fat-soluble vitamins

9 kcal/g for lipids compared to 4 kcal/g for carbohydrates and proteins, lipids are an excellent source of energy.

Lipids are key components of the cell membrane, and they serve as chemical messengers in the body.

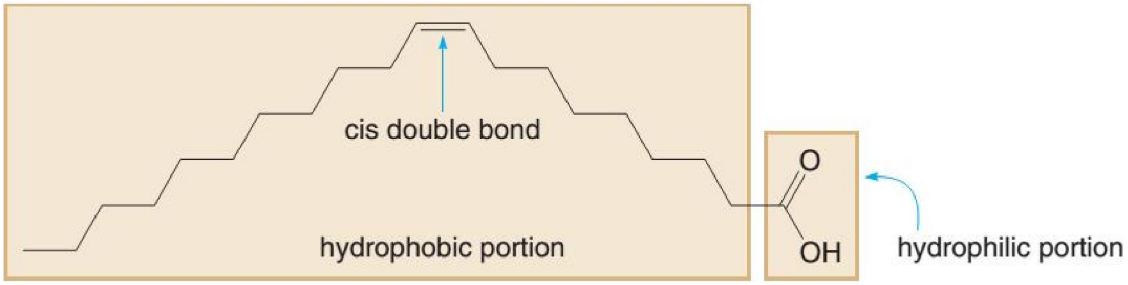
FATTY ACIDS

Fatty acids are carboxylic acids (RCOOH) with long carbon chains of 12–20 carbon atoms.



- ✓**Saturatedfatty acids have no double bonds in their long hydrocarbon chains.**
- ✓**Unsaturatedfatty acids have one or more double bonds in their long hydrocarbon chains.**

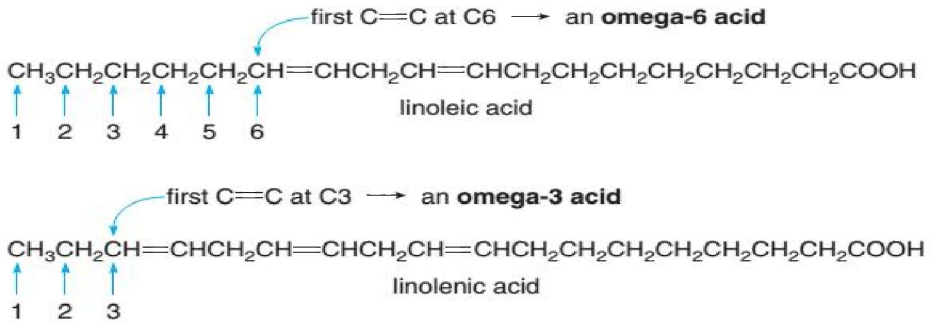
- ✓ **Generally, double bonds in naturally occurring fatty acids are cis**



Number of C's	Number of C=C's	Structure	Name	Mp (°C)
Saturated Fatty Acids				
12	0	$CH_3(CH_2)_{10}COOH$	Lauric acid	44
14	0	$CH_3(CH_2)_{12}COOH$	Myristic acid	58
16	0	$CH_3(CH_2)_{14}COOH$	Palmitic acid	63
18	0	$CH_3(CH_2)_{16}COOH$	Stearic acid	71
20	0	$CH_3(CH_2)_{18}COOH$	Arachidic acid	77
Unsaturated Fatty Acids				
16	1	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	Palmitoleic acid	1
18	1	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	Oleic acid	16
18	2	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	Linoleic acid	-5
18	3	$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	Linolenic acid	-11
20	4	$CH_3(CH_2)_4(CH{=}CHCH_2)_4(CH_2)_2COOH$	Arachidonic acid	-49

❖Unsaturated fatty acids are sometimes classified as omega-nacids,where nis the carbon at which the first double bond occurs in the carbon chain, beginning at the end of the chain that contains the CH3 group.

❖Thus, linoleic acid is an omega-6 acid and linolenic acid is an omega-3 acid.


first C=C at C6 → an **omega-6 acid**
$CH_3CH_2CH_2CH_2CH_2CH{=}CHCH_2CH{=}CHCH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$
1 2 3 4 5 6
linoleic acid
first C=C at C3 → an **omega-3 acid**
$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$
1 2 3
linolenic acid

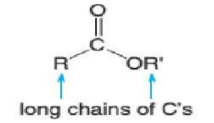
- As the number of double bonds in the fatty acid *increases*, the melting point *decreases*.

WAXES

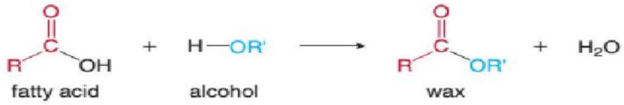
Waxes are the simplest hydrolyzable lipids.

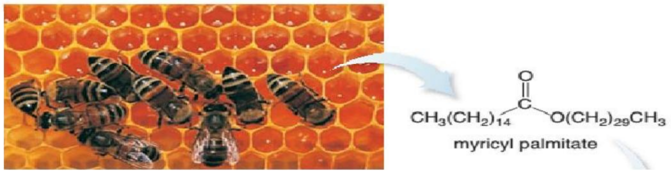
- *Waxes* are esters (RCOOR') formed from a fatty acid (RCOOH) and a high molecular weight alcohol (R'OH).

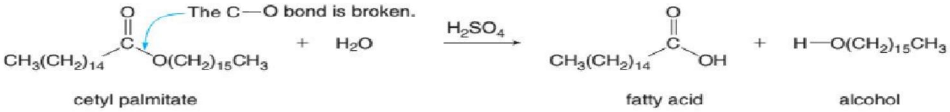
Wax General structure



Formation



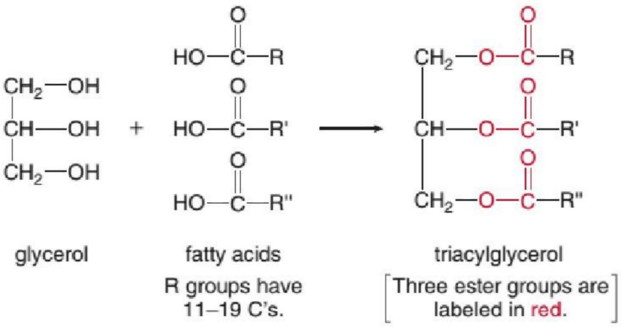


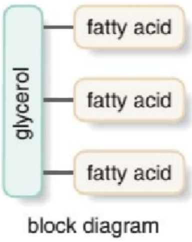


TRIACYLGLYCEROLS—FATS AND OILS

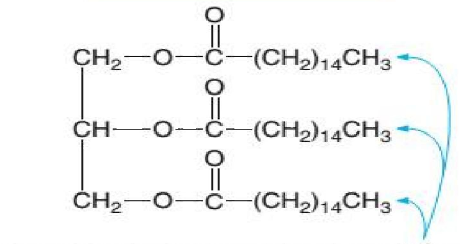
Animal fats and vegetable oils, the most abundant lipids, are composed of **triacylglycerols.**

- *Triacylglycerols,* or triglycerides, are triesters formed from glycerol and three molecules of fatty acids.



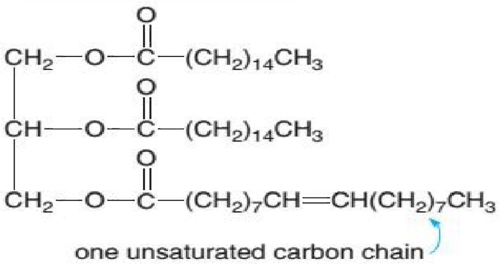


Simple triacylglycerol



three identical saturated carbon chains

Mixed triacylglycerol



one unsaturated carbon chain

✓Fats have higher melting points—they are solids at room temperature.
✓Oils have lower melting points—they are liquids at room temperature.

✓Fats are derived from fatty acids having few double bonds. are generally animal in origin
✓Oils are derived from fatty acids having a larger number of double bonds. and are generally vegetable in origin.

❖Drug Administration recommends that no more than 20–35% of an individual's calorie intake come from lipids.

❖ Moreover, a high intake of saturated triacylglycerols is linked to an increased incidence of heart disease.

❖ Saturated fats stimulate cholesterol synthesis in the liver and transport to the tissues, resulting in an increase in cholesterol concentration in the blood.

❖ An elevated cholesterol level in the blood can lead to cholesterol deposits or plaques on arteries, causing a narrowing of blood vessels, heart attack,

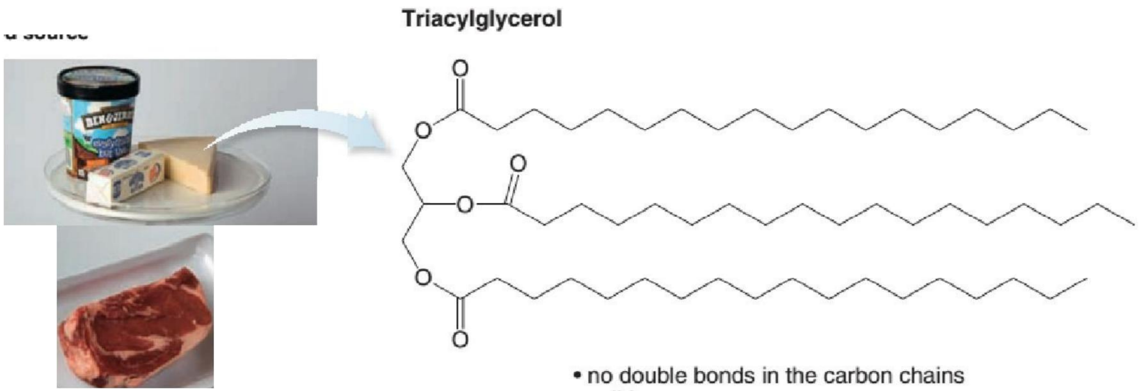
❖In contrast, unsaturated triacylglycerols lower the risk of heart disease by decreasing the amount of cholesterol in the blood.

❖Unsaturated triacylglycerols from omega-3 fatty acids appear to reduce the risk of heart attack,

❖Trans fats are formed when liquid oils are partially hydrogenated to form semi-solid triacylglycerols.

❖The three-dimensional structure of a trans triacylglycerol shows its similarity to saturated triacylglycerols.

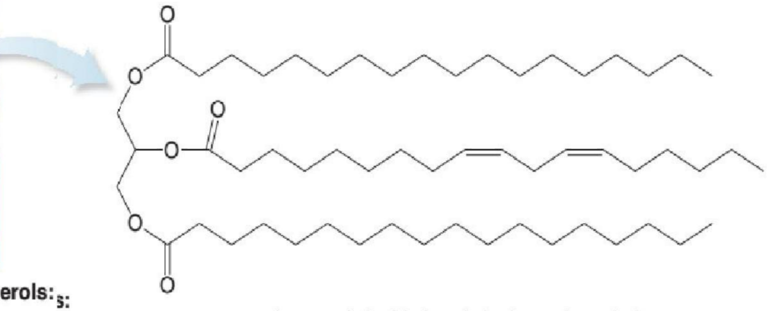
❖ Like saturated fats, trans fats also increase the amount of cholesterol in the bloodstream, thus increasing an individual’s risk of developing coronary artery disease.



- no double bonds in the carbon chains
- solid at room temperature
- increases blood cholesterol level

Foods rich in saturated triacylglycerols: fatty red meat, cheese,

Foods rich in unsaturated triacylglycerols:s:
plant oils, nuts, soybeans, fish (salmon, herring, mackerel)

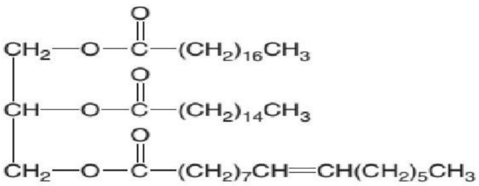


- one (or more) double bonds in the carbon chains
- liquid at room temperature
- decreases blood cholesterol level

Foods rich in trans triacylglycerols: margarine, processed foods, fried foods

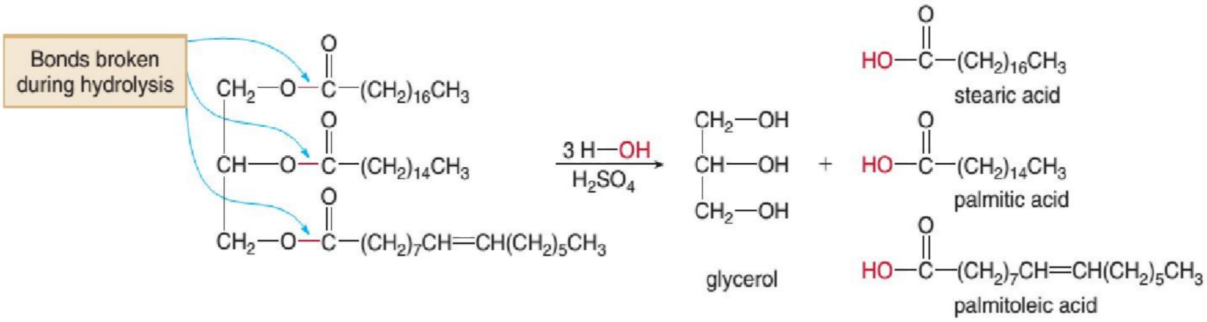
---

Draw the products formed when the given triacylglycerol is hydrolyzed with water in the presence of sulfuric acid.



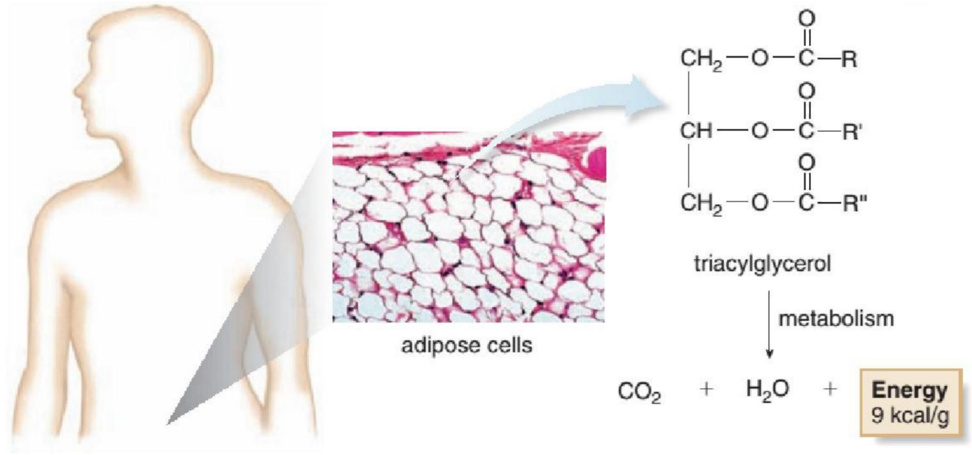
$$\begin{array}{l} CH_2-O-\overset{O}{\overset{\|}{C}}-(CH_2)_{16}CH_3 \\ | \\ CH-O-\overset{O}{\overset{\|}{C}}-(CH_2)_{14}CH_3 \\ | \\ CH_2-O-\overset{O}{\overset{\|}{C}}-(CH_2)_7CH=CH(CH_2)_5CH_3 \end{array}$$

SOLUTION Hydrolysis forms glycerol and stearic, palmitic, and palmitoleic acids.


Bonds broken during hydrolysis
$CH_2-O-\overset{O}{\overset{\|}{C}}-(CH_2)_{16}CH_3$
$CH-O-\overset{O}{\overset{\|}{C}}-(CH_2)_{14}CH_3$
$CH_2-O-\overset{O}{\overset{\|}{C}}-(CH_2)_7CH=CH(CH_2)_5CH_3$
3 H—OH
H_2SO_4
CH_2-OH
$CH-OH$
CH_2-OH
glycerol
+
$HO-\overset{O}{\overset{\|}{C}}-(CH_2)_{16}CH_3$
stearic acid
$HO-\overset{O}{\overset{\|}{C}}-(CH_2)_{14}CH_3$
palmitic acid
$HO-\overset{O}{\overset{\|}{C}}-(CH_2)_7CH=CH(CH_2)_5CH_3$
palmitoleic acid

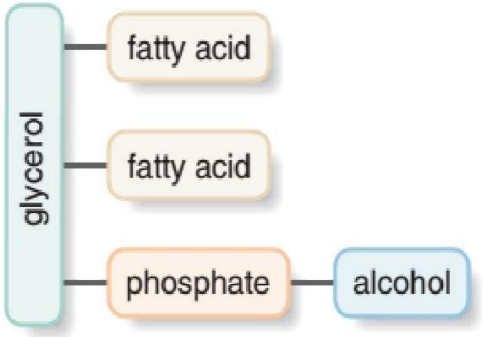
FOCUS ON THE HUMAN BODY

The Storage and Metabolism of Triacylglycerols

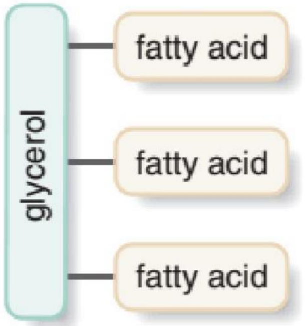


Triacylglycerols are stored in adipose cells below the skin and concentrated in some regions of the body. The average fat content of men and women is ~20% and ~25%, respectively. This stored fat provides two to three months of the body's energy needs.

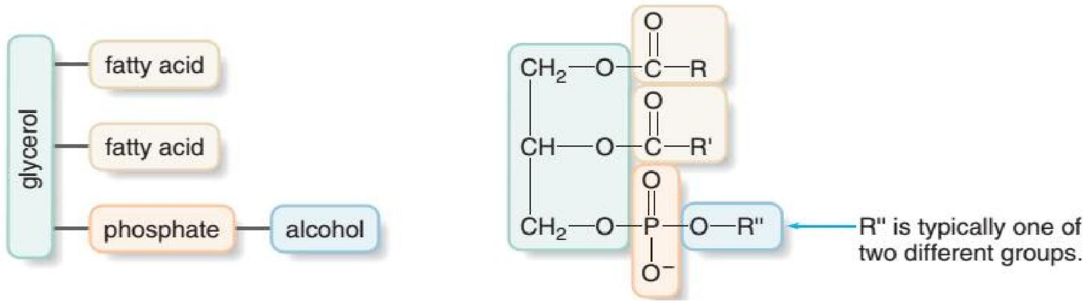
PHOSPHOLIPIDS



phosphoacylglycerol



triacylglycerol



General structure of a phosphoacylglycerol

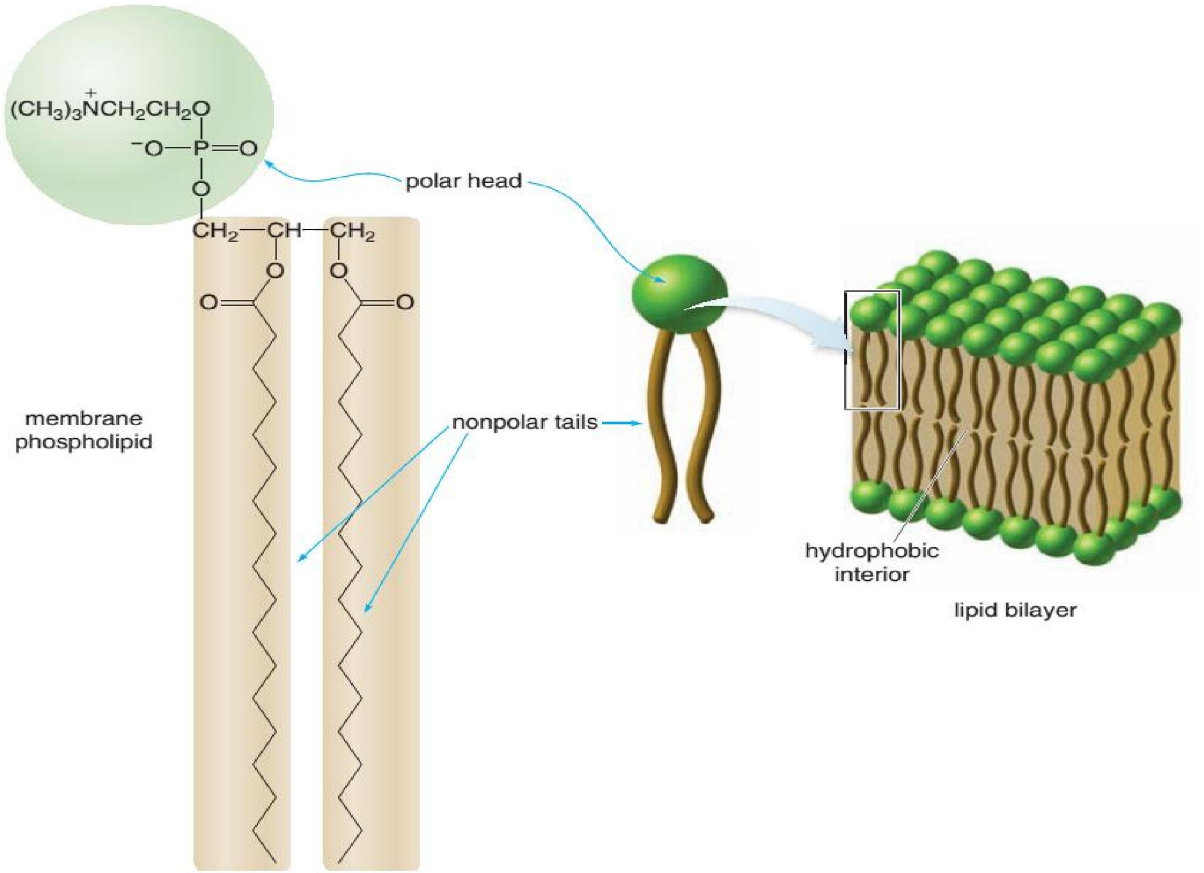
R'' is typically one of two different groups.

CELL MEMBRANES

❖Phospholipids, especially phosphoacylglycerols, are the major component of the cell membrane.

❖Phospholipids contain a hydrophilic polar head and two nonpolar tails composed of C C and C H bonds.When phospholipids are mixed with water, they assemble in an arrangement called a lipid bilayer,with the ionic heads oriented on the outside and the nonpolar tails on the inside.

❖ The polar heads electrostatically interact with the polar solvent H2O, while the nonpolar tails are held in close proximity by numerous London dispersion forces (vanderwaals)



❖**When the fatty acids are saturated, they pack well in the interior of the lipid bilayer, and the membrane is less fluid.**

❖**When there are many unsaturated fatty acids, the nonpolar tails cannot pack as well and the bilayer is more fluid.**